Composites Research and Technology For Aerospace Vehicles

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Outline

- Today's Lessons Learned
- Materials and Structures Technology Development
- Future Materials and Structures Applications

Materials, Processes, and Manufacturing

Lessons Learned

1. Materials development in conjunction with product development creates undue risks.

2. **Experienced materials and processing engineers should be included in the design phase and must be readily available to correct problems in production processes.**

3. Manufacturing process scale-up development tests should be conducted to optimize the production processes.

4. Co-curing and co-bonding are preferred over secondary bonding which requires near perfect interface fit-up.

5. Mechanically fastened joints require close tolerance fit-up and shimming to assure a good fit and to avoid damage to the composite parts during assembly.

6. Dimensional tolerances are more critical in composites than in metals to avoid damage to parts during assembly. Quality tools are essential to the production of quality parts.

7. Selection of the tool material depends on part size, configuration, production rate, quantity, and company experience.

8. Tool designers should anticipate the need to modify tools to adjust for part springback, ease of removal, or maintain dimensional control of critical interfaces.

Structural Design, Analysis, and Testing

Lessons Learned:

1. Design and certification requirements for composite structure are generally more complex and conservative than for metal structure.

2. Successful programs have used the building-block approach with a realistic schedule that allows for a systematic development effort.

3. The use of basic laminates containing 0/90/+45/-45 plies with a minimum of 10% of the plies in each direction is well suited to most applications.

4. Mechanical joints should be restricted to attachment of metal fittings and situations where assembly or access is impractical using alternative approaches.

5. Large, co-cured assemblies reduce part count and assembly costs but may require complex tooling.

6. Structural designs and the associated tooling should be able to accommodate design changes associated with the inevitable increases in design loads.

7. Understanding and properly characterizing impact damage would eliminate confusion in the design process and permit direct comparison of test data.

Quality Control, NDE/I, and Supportability

Lessons Learned:

1. Automated processes can help to reduce QC costs.

2. Inspection and quality control should focus on aspects of the process and part that have a direct bearing on part performance.

3. Determine and understand the effects of defects on part performance.

4. **Supportability should be addressed during design so that composite structures are inspectable, maintainable and repairable.**

5. Most damage to composite structure occurs during assembly or routine maintenance of the aircraft.

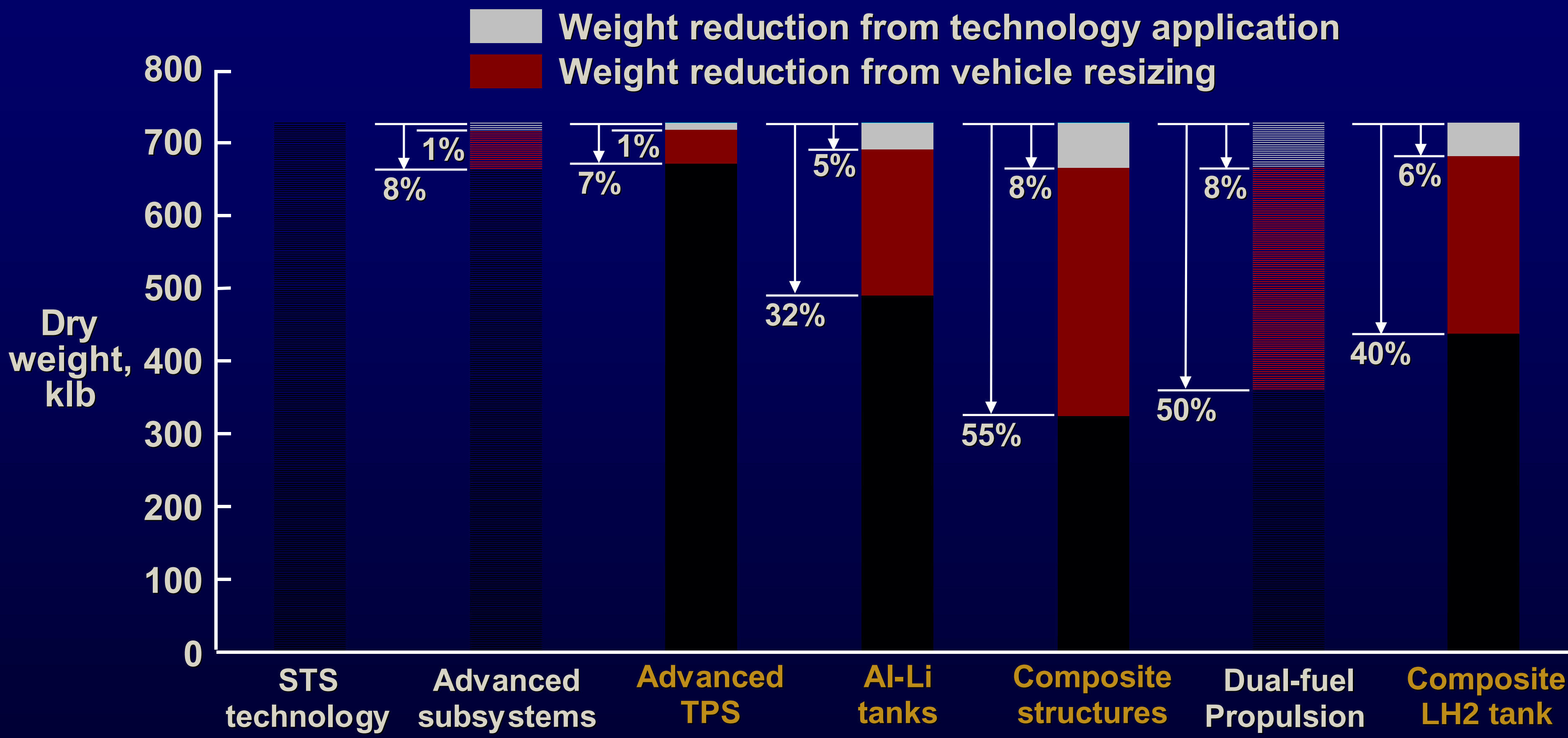
6. Repair costs are much higher than for metal structures.

7. Improved Standard Repair Manuals are needed for in-service maintenance and repair.

8. Special long-life and low-temperature curing repair materials are required.

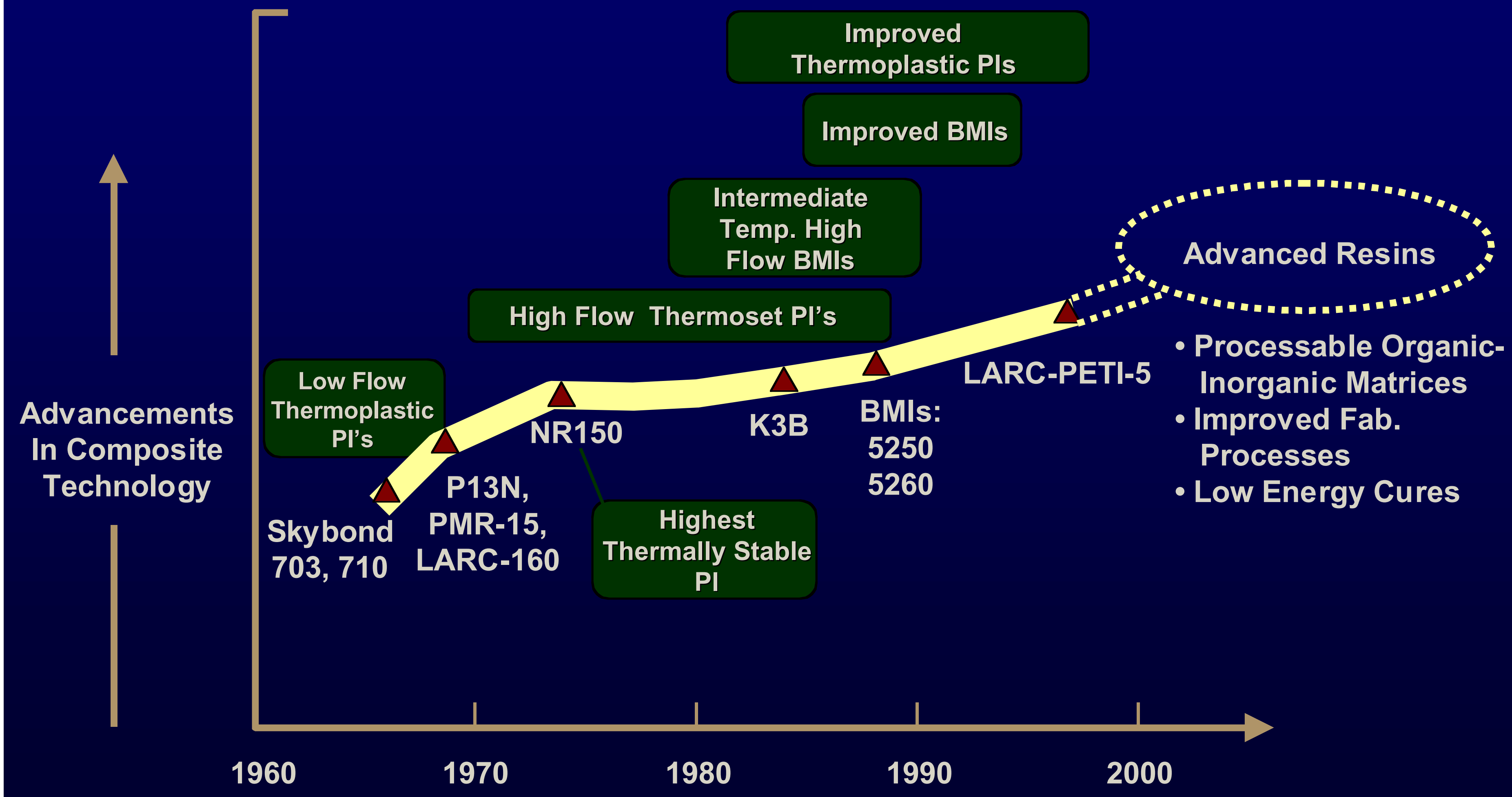
9. Moisture ingestion and aluminum core corrosion are recurring supportability problems for honeycomb structures.

Predicted Weight Savings from Incorporation of Advanced Technologies

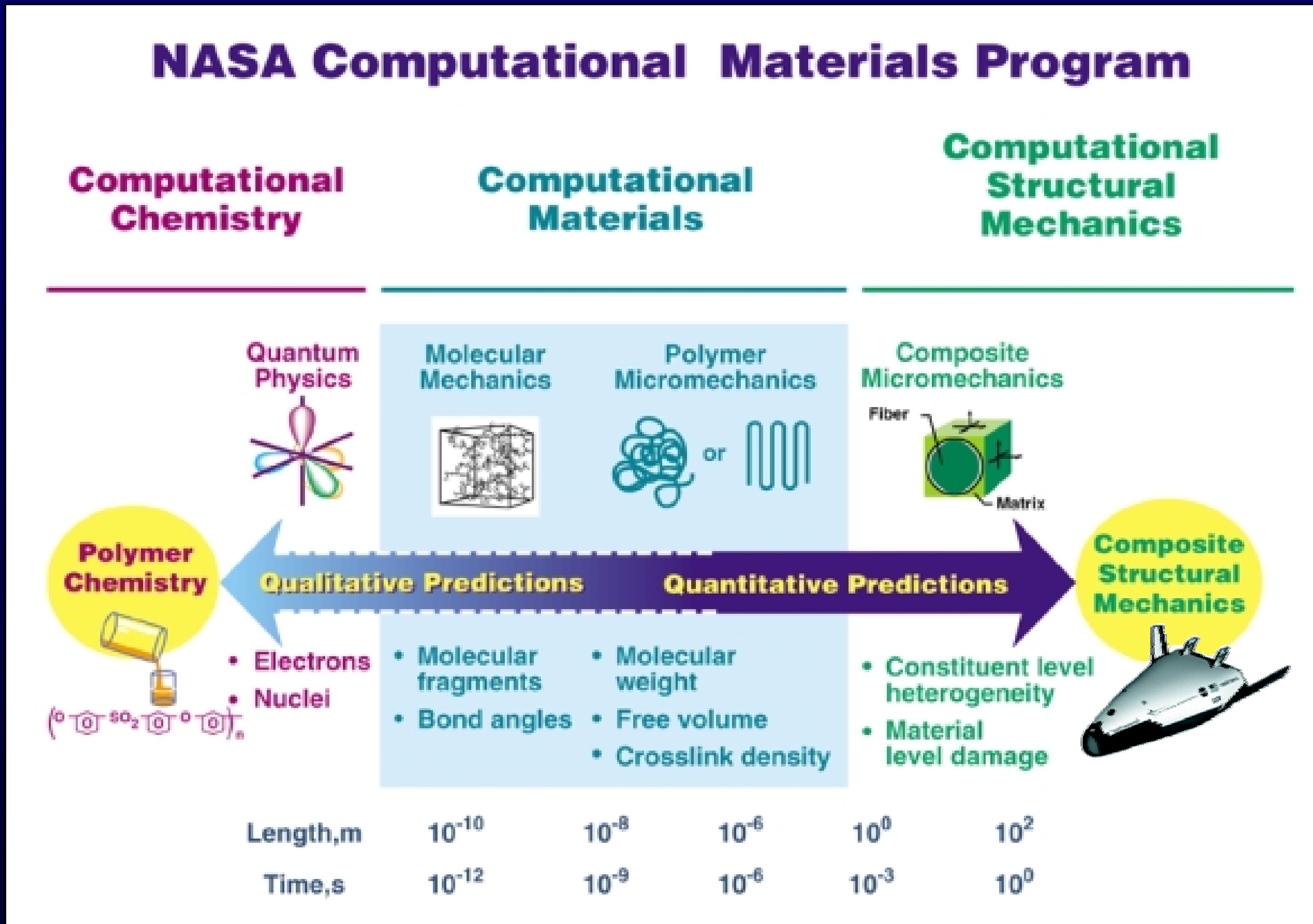


Major Weight & Cost Reductions are Possible from Advanced Airframe Structures and Materials!

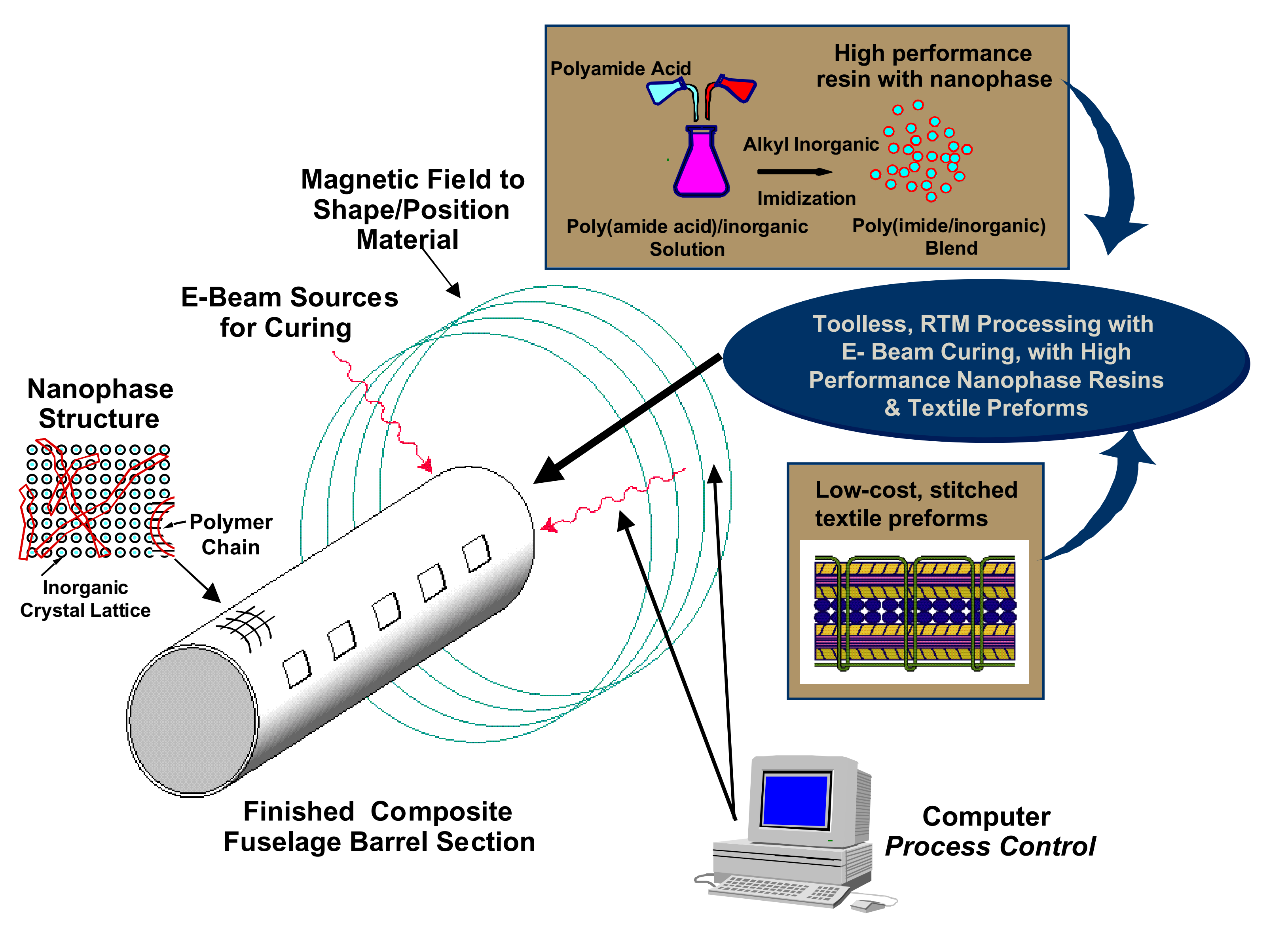
Evolution of Composite Resin Development:
Intermediate & High Temperature Resins



Computationally Designed Materials and Structures

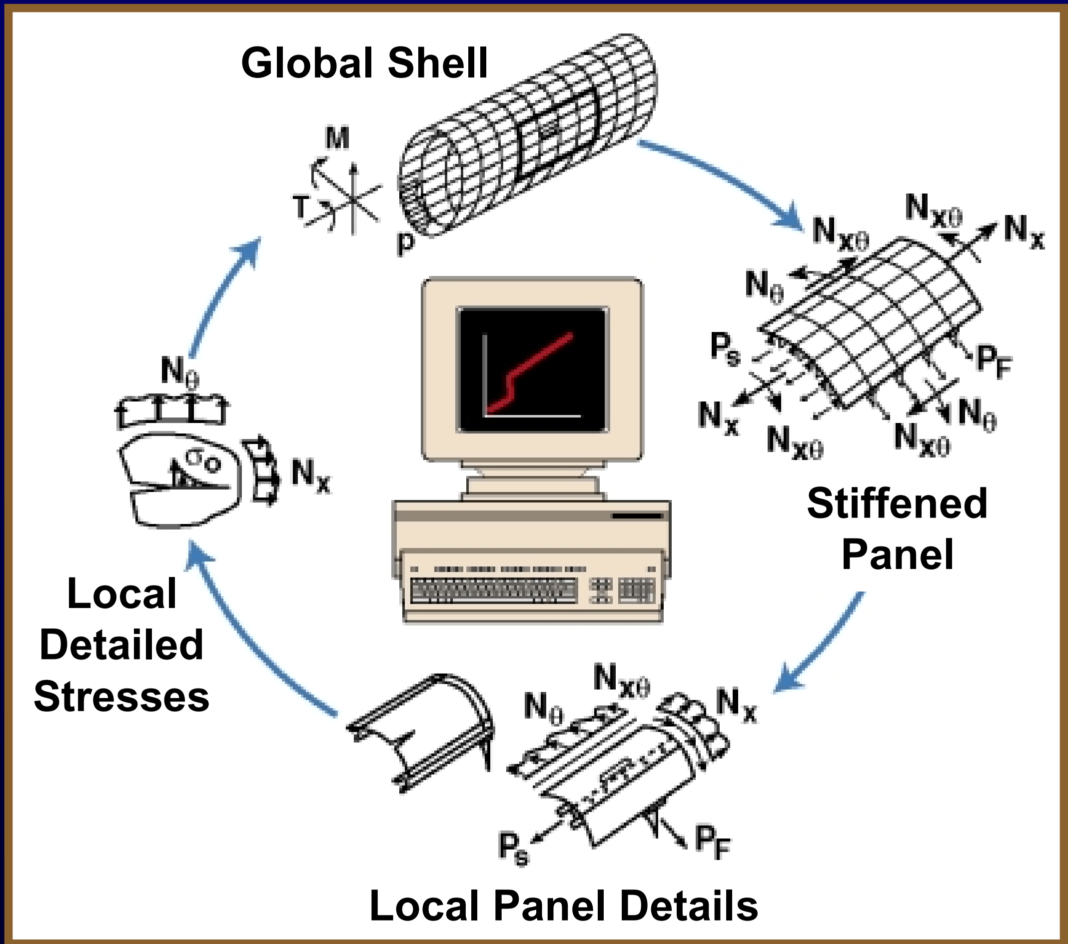


Low-Cost Composites Processing of the Future

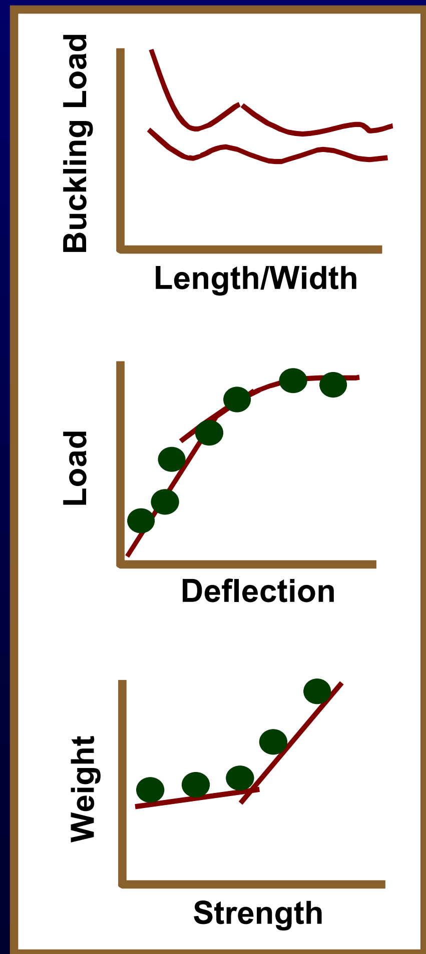


Global/Local Analysis for Predicting Structural Behavior

Analysis Methodology



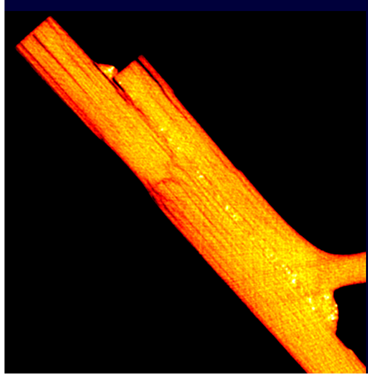
Predicted Behavior



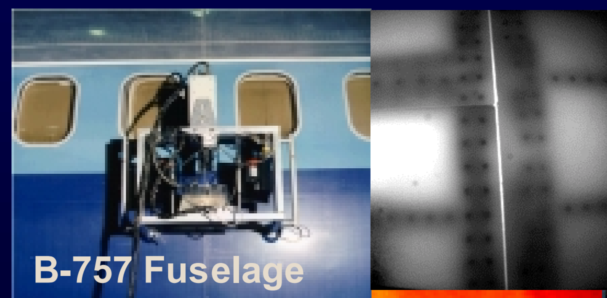
Advancing NDE Technologies Toward Complex Structures

Eddy Current

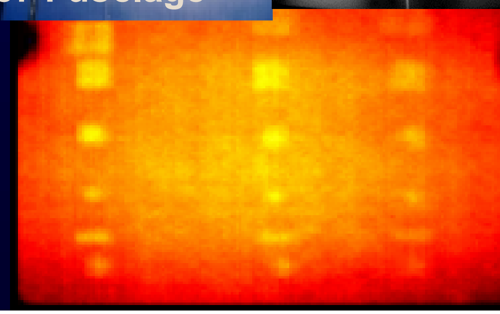
Ultrasonics

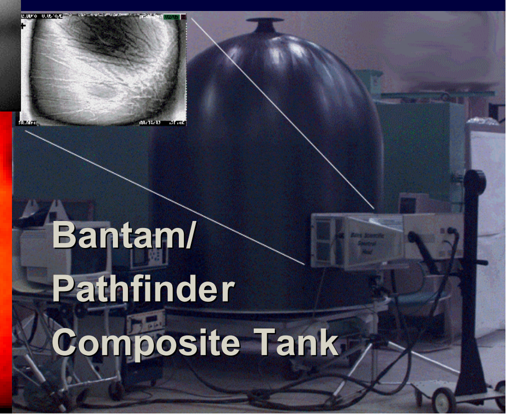


X-Ray Tomography

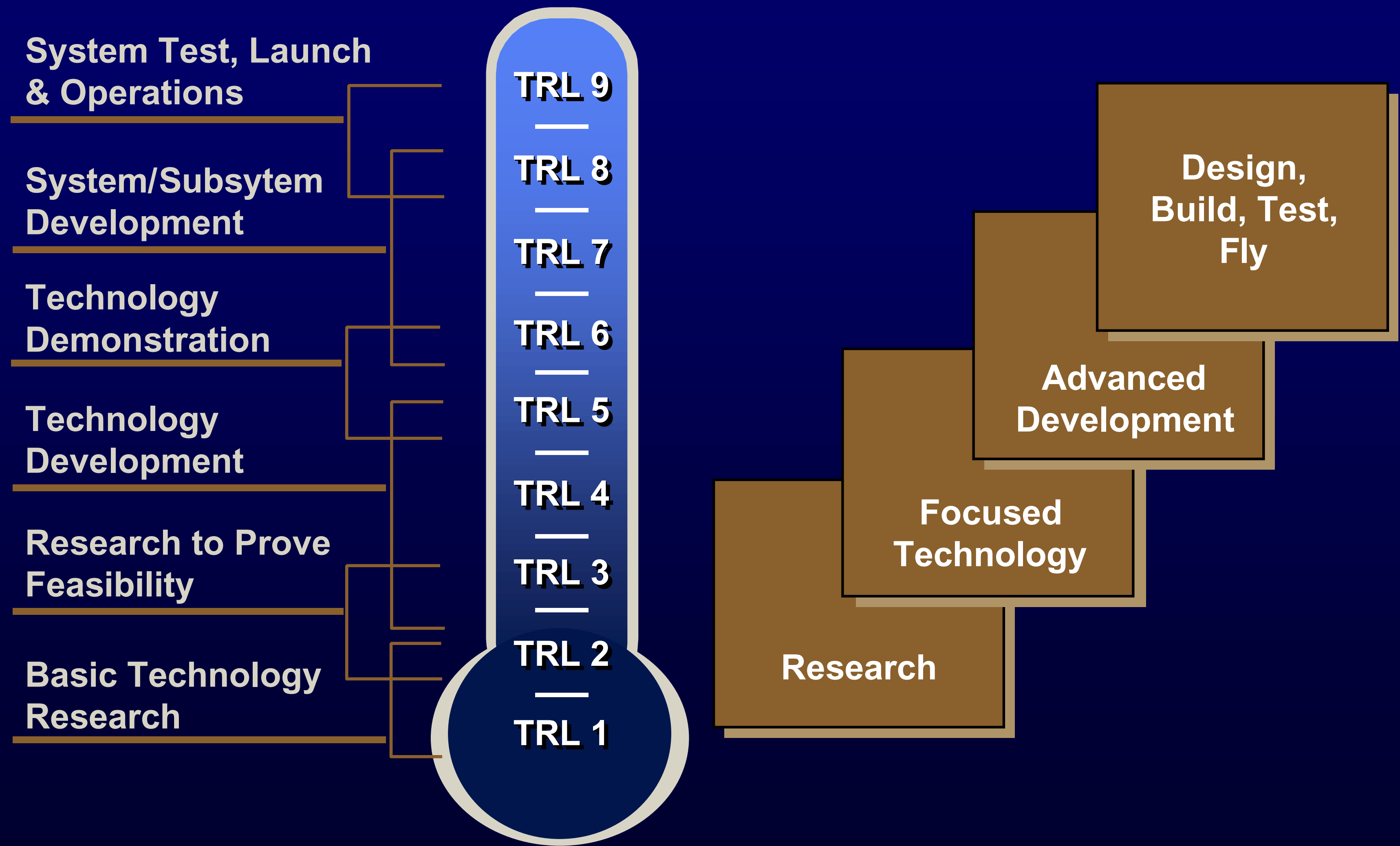


Thermal





NASA Technology Readiness Levels (TRL)



Assessment of Technology Needs for an RLV

Leading Edges / Nose Caps

- Refractory composites (TRL=9)
- Hot-structure control surfaces (TRL=5)

Thermal Protection System

- High temperature metallics (TRL=5)
- Refractory composites (TRL=4)
- Advanced flexible insulation (TRL=6)

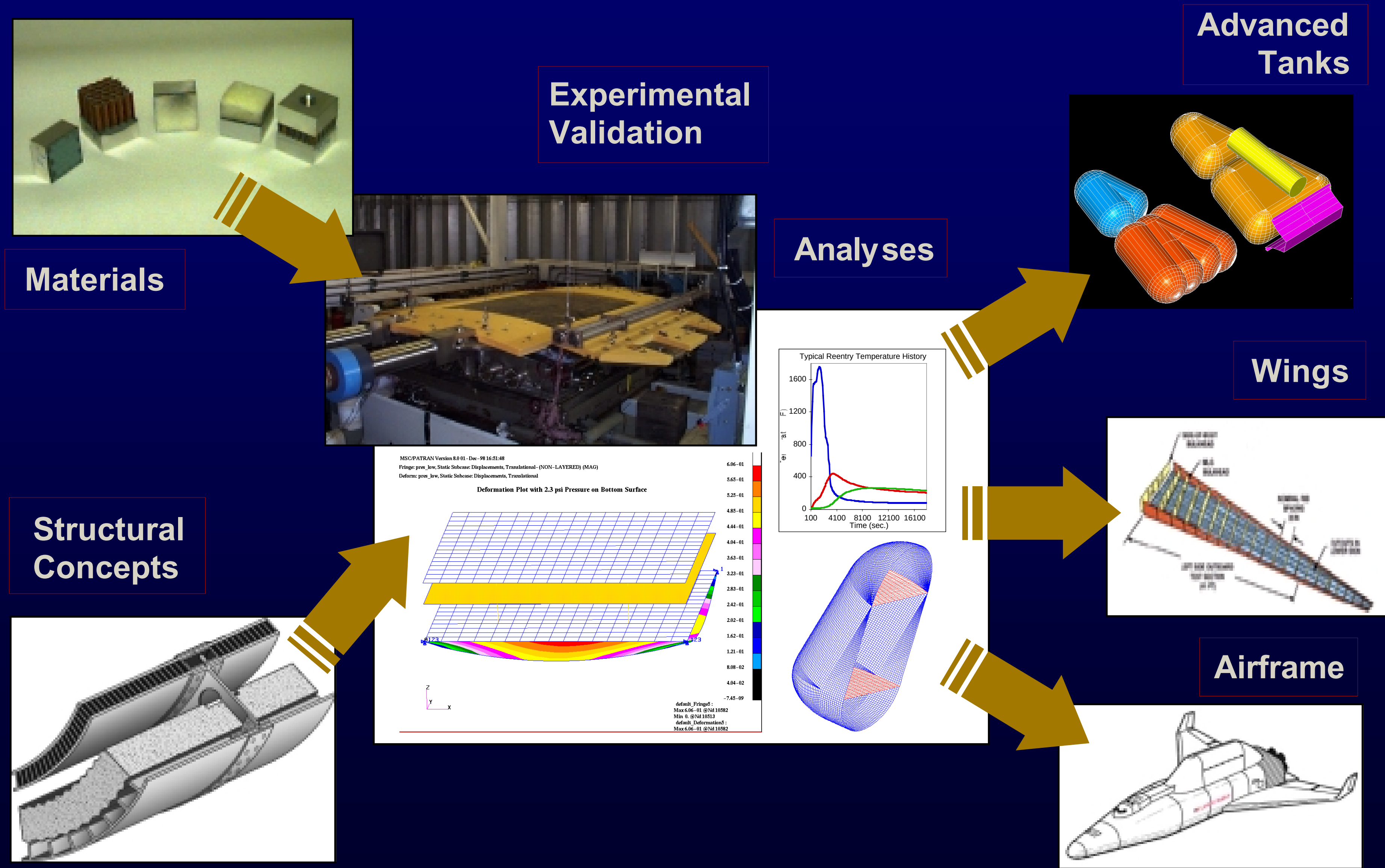
Primary Structure

- High-temperature metal composites (TRL=4)
- Noncircular composite shell structures (TRL=3)
- Joints and attachment techniques (TRL=4)
- Nondestructive evaluation (TRL=4)
- Manufacturing technology (TRL=4)

Cryotanks

- Sandwich construction (TRL=4)
- Nonautoclave curing (TRL=3)
- Nondestructive evaluation (TRL=4)
- Vehicle health monitoring (TRL=3)
- Integrated TPS / cryoinsulation (TRL=2)

A Complete Integrated Structures and Materials Program for RLV Airframe Systems



Programs, Products, and Services for 2009

1. Application-Specific Aero-space Programs
   - Affordable “Point-to-Point” Personal Aircraft
   - Large Transport Aircraft (e.g., Blended-Wing Body)
   - Sensorcraft
   - Lunar/Mars Transportation Vehicles for Human Exploration
2. Brilliant Products and Systems
   - Multifunctional Materials and Structures
   - Highly-Integrated Instruments and Structures for Sensorcraft
   - Ultra-Smart Materials and Structures
   - Radiation Effects and Radiation Shielding Materials
3. Computing, Design, and Analysis Methods and Tools
   - Optical, Quantum, and Biological Computers
   - Fully Immersive Concept-To-Flight Design Environment
   - Flexible Integration of Modeling and Design Techniques
   - Intelligent agents, Fuzzy, and Nondeterministic Analysis Methods
4. Experimental Methods and Test Techniques
   - Remote access to facilities and laboratories through virtual reality
   - Automated, Digitally-Controlled Testing Techniques

Structures & Materials Skills Evolution

- Classical metals, polymers, ceramics, and composites development skills transitioning to nano-, smart-, functionally graded, multifunctional, environmentally friendly, computational, and biomimic designed M&S systems

- Classical applied mechanics, dynamics, aeroelasticity, and computational methods skills transitioning to multidisciplinary computational aero-servo-thermal-structure-materials methodology; and mathematically nondeterministic, nonlinear, fuzzy, probabilistic, design and analysis tools

- Traditional point-by-point external diagnostic sensors skills transitioning to intelligent, distributed, in-situ diagnostic, and self-healing systems.

Areas of Expertise at NASA Langley Research Center

AoE 1. Develop advanced **materials and processing technologies** to enable the fabrication of low-cost and high-performance structural concepts for aerospace applications.

AoE 2. Conduct research and technology development that accurately and efficiently predict **behavior, durability and damage tolerance,** evaluates **concepts, and validates** performance of advanced materials and structures for aerospace structural applications.

AoE 3. Conduct research and technology development for advanced **sensors, intelligent systems, and ground operations** to ensure structural integrity, reliability, and safety for aerospace vehicles.

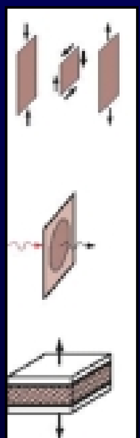
AoE 4. Conduct research and technology development to quantify and control **aeroelastic response, unsteady aerodynamic** flow phenomena, **and structural dynamics** behavior for aerospace vehicles.

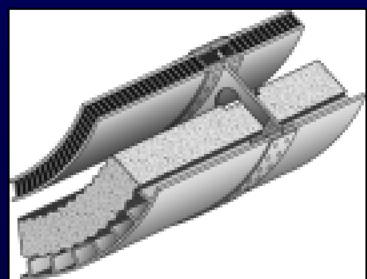
Concluding Remarks

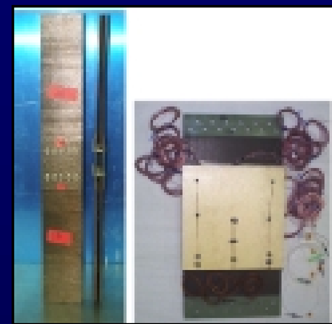
- New materials, processing, structural concepts, and sensors will enable dramatically improved applications
- Reusable launch vehicles and future spacecraft will demonstrate advanced materials and structures technologies

Development of Advanced Cryotank and Airframe Structures Building-Block Approach

- Mechanical Properties
- H2 Permeability tests (4 in. x 4 in.)
- Flatwise Tension Tests (2 in. x 2 in.)







Full-Scale Structural Verification

Concept Demonstration at Component Level

- Gr-Ep/Foam Panel (LaRC TEEK HH)
- Thermally Cycled PMC/Foam Insulation
- Fluted Core Splice Joint

Manufacturing Process Development and Scale-up

Design Concepts and Analysis Development

Coupon Testing for Material Properties

Application of LaRC-Developed Materials

Tethers for Propellant-Free Propulsion

- Atomic Oxygen Resistance
- High Specific Strength
- Selected for ProSEDS Flight Demonstration

Solar Thermal Propulsion Upperstage

- Low Color, Low Solar Absorption
- High Reflectivity
- Selected for Primary Collector on Boeing's SOTV

New/Enhanced Facilities Required for 2009

- Cargo hold and fuel tank explosions
- Modify Aircraft Landing Dynamics Facility (high load, high speed, larger tires)*
- High-temperature and cryo-temperature capability for COLTS*
- Electro-Magnetic upgrade to TDT*
- Hypersonic flow simulation (ARC Jet)
- Nano-sensor facility*
- In-Situ Materials Processing Lab
- Laser Deposition Fabrication Lab
- High-conductivity property characterization
- Advanced automated materials manufacturing lab
- Biochemistry Lab*
- Large graphitization fabrication facility
- Free-form fabrication facility
- Large brazing fabrication facility
- Rapid prototyping fabrication lab
- 3-D virtual reality computational test lab*

*Facilities located at LaRC

Evolution of Composite Resin Development: *Epoxies*